EVALUATING THE TRADE-OFFS OF COVER CROPS IN DRYLAND WHEAT SYSTEMS OF THE COLORADO PLATEAU

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ABSTRACT

On the semi-arid Colorado Plateau, dryland farmers are challenged by severely degraded soils and low and increasingly unreliable precipitation. Cover crops have been shown to improve soil fertility and mitigate soil erosion in many regions, but are also associated with use of limited soil moisture, a cost that could mean decreased cash crop productivity for farmers. Most literature on cover crops comes from relatively humid climates, where crop yield penalties due to cover crops may be less pronounced. Our research seeks to assess the viability of cover crops as a solution to soil degradation and erosion in dryland systems on the Colorado Plateau, through the implementation of two field experiments at the Southwestern Colorado Research Center in Yellow Jacket, CO starting in 2015. The yield penalties of winter wheat following cover crop growth ranged from 22% to 78% and varied according to year and the amount of cover crop biomass produced in the year prior to wheat planting. The wheat yield penalty was likely due to lowered soil moisture content and nitrogen availability observed in cover crop treatments as compared to the fallow controls. However, increasing trends in soil carbon and aggregation in plots that had received two cycles of cover crops show the potential for cover crops to improve soil fertility in these dryland systems, though these changes in soil health typically occur over a longer time frame. These experiments will be continued and changes in soil health and wheat productivity will be monitored to assess the potential for cover crops to improve soil health in the long-term.

INTRODUCTION

The high desert region of the Colorado Plateau is characterized by high elevation (1800-3000 m) and low and increasingly unreliable precipitation (180-300 mm yr^{-1}). To minimize transpiration and recharge soil moisture, dryland producers typically leave land fallow for 14-month periods and rely heavily on tillage and herbicides to control weeds. Soils in these systems have consequently experienced severe degradation associated with wind erosion and low organic matter/nutrient inputs, and producers in the region are becoming increasingly concerned with the long-term maintenance of soil fertility and productivity on their farms.

Cover crops have been put forth as a potential solution to increase soil water capture, while also reducing erosion, sequestering soil carbon and improving overall soil health (Snapp et al., 2005; Schipanski et al., 2014). By decreasing runoff, cover crops may allow soils to better retain rainfall from intense storms and increase cropping system resilience in drought years. However, tradeoffs are inevitable and cover crops can also compete for water with cash crops. Cover crop impacts on soil health and cash crop yields are context-dependent and vary according to climatic conditions as well as local management practices. While cover crop impacts are better understood in wetter climates, data for the Colorado Plateau and similar semi-arid regions are notably lacking.

This research aims to assess the viability of cover crops as a means to address soil degradation on the Colorado Plateau by quantifying impacts on both cash crop yields and soil health metrics over time. Data from field experiments will help assess how cover crop management practices- including planting window, cover crop mixture, and tillage- contribute to these impacts.

MATERIALS AND METHODS

Two field trials were established on the Southwestern Colorado Research Station (SWCRC) in Yellow Jacket, CO to evaluate various cover crop mixtures in a controlled setting. The first field trial (SWCRC1) was established in August 2015 and compared three cover crop mixtures vs. a fallow control in a randomized complete block (RCB) design with three replicate plots. Plots followed a two-year cycle with 10 months in cover crops, a 2-month fallow period, 10 months in winter wheat, and another 2-month fallow period.

In August 2016 a second replicated trial (SWCRC2) was established with nine cover crop mixtures including both spring- and fall-planted mixtures. The experiment also examined these cover crop treatments within two tillage regimes (no-till vs. conventional tillage) and employs a RCB design. All cover crop mixtures were followed by winter wheat, which was harvested in July 2018.

Cover crop biomass data were collected at cover crop termination using a 75 cm dia. range hoop and returned to the lab for sorting by plant functional group, oven-drying at 60 °C and weighing. Wheat yield and quality were measured following wheat maturity. Bulk density and aggregate stability were measured at cover crop termination in the top layer (0-5 cm) of soil to evaluate soil compaction and structure. Soil moisture was evaluated using soil cores, taken to a depth of 1 m at cash crop planting. Soil fertility was assessed for total organic C and N, pH, and available N.

All data were analyzed in R statistical software (R Core Team, 2017). Cover crop production, wheat yields, and soil health metrics were analyzed using a multifactor ANOVA, with cover crop treatment included as a fixed effect and block included as a random effect. Tukey-adjusted pairwise comparisons, generated by the emmeans package in R (Lenth, 2018), were used to estimate the difference between treatments.

RESULTS AND DISCUSSION

Cover Crop Biomass

Average cover crop biomass varied by year, according to differences in precipitation patterns. Biomass produced ranged from an average of 5020 ± 418 kg/ha in 2016 to 1510 ± 110 kg/ha in 2018, when the region experienced severe drought (Fig. 1). In SWCRC2, the planting window of the cover crop significantly impacted total biomass, with fall-planted mixtures producing significantly more total biomass than spring-planted mixtures. Within planting window, however, mixtures did not significantly differ in terms of total biomass produced ($p>0.05$).

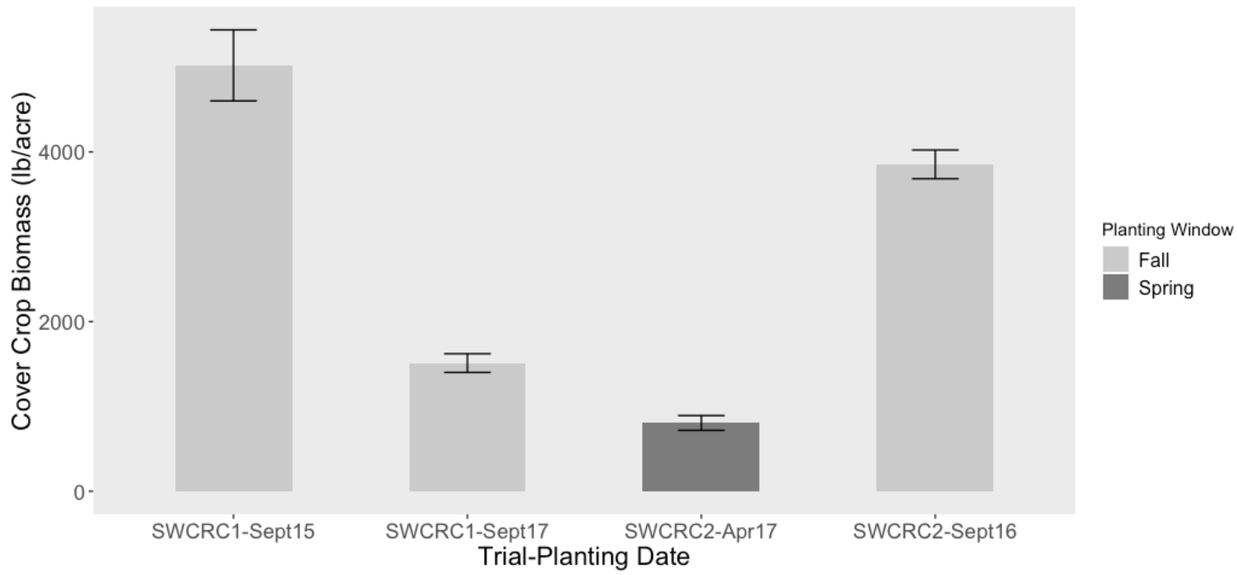

Figure 1. Cover crop biomass in two field experiments located at the Southwestern Colorado Research Center in Yellow Jacket, CO over three growing seasons with both fall- and spring-planted cover crop mixtures. Error bars represent standard error of the mean.

Winter Wheat Yields

In SWCRC1, the wheat yield penalty, or percent decrease in wheat yield following the cover crop treatment as compared to the fallow treatment, was on average 27% in 2017. The wheat yield penalty in SWCRC2 was dependent on the planting window of the cover crop, and was less in the spring-planted cover crop plots (22%) compared to fall-planted cover crop plots (78%; $p<0.0001$). Wheat yields following the fallow treatment had the highest average yield, but did not significantly differ from the spring-planted treatments ($p=0.12$). The amount of cover crop biomass produced was a main driver in subsequent wheat yields, as evidence by the linear regression between 2017 cover crop biomass and 2018 wheat yields in SWCRC2 (Fig. 2; $R^2=0.53$; $p<0.001$).

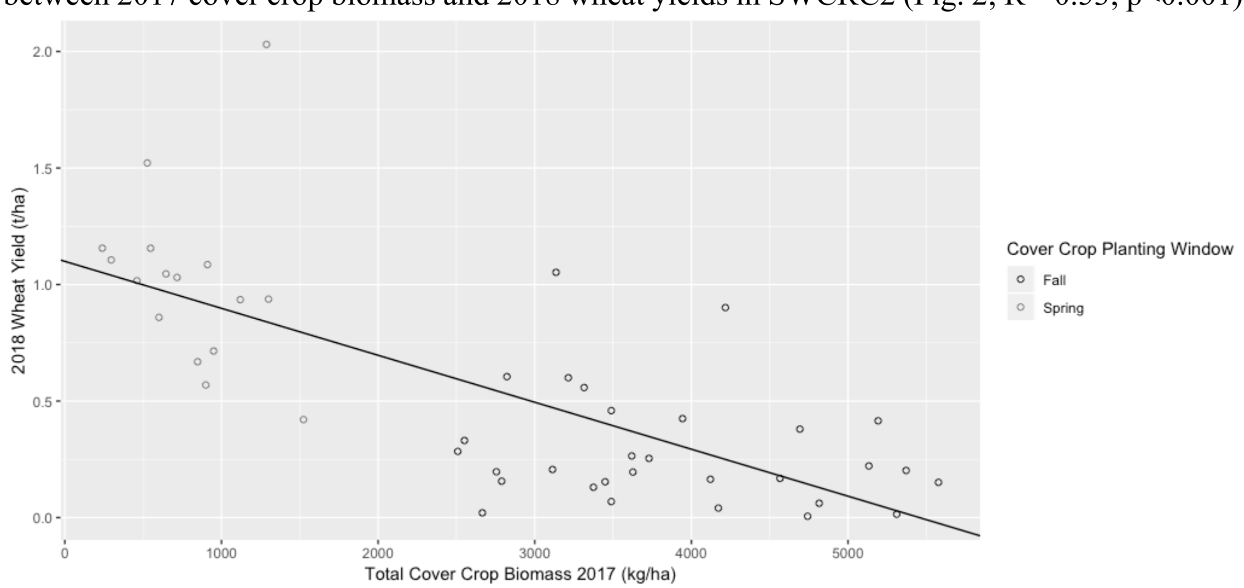

Figure 2. Correlation ($R^2=0.53$ $p<0.001$) between cover crop biomass (2017) and subsequent winter wheat yields (2018) in a field experiment (SWCRC2) located at the Southwestern Colorado Research Center in Yellow Jacket, CO.

Soil moisture and soil nitrate levels were both lowest in fall-planted cover crop treatments, highest in the fallow, and intermediate for the spring-planted treatments (Table 1). Soil moisture in particular is widely accepted as the main limitation to crop production on the Colorado Plateau and could explain the lowered wheat yields following cover crop growth. However, available nitrogen is also a known limiting factor to wheat production, especially since dryland systems in this region are not customarily fertilized. Nitrogen immobilized in cover crop biomass is not lost from the system, but will take time to be mineralized back into the soil and made available for cash crop use.

Table 1. Moisture content at 0-30, 30-60, and 60-90 cm and soil nitrate levels between fall-planted cover crop mixtures, spring-planted cover crop mixtures, and a fallow treatment in a field experiment in Yellow Jacket, CO. Measurements were taken at winter wheat planting in September 2017. Values in parentheses represent standard error of the mean.

	Fall-Planted	Spring-Planted	Fallow
Moisture Content at 0-30 cm (g g^{-1})	0.12 (0.0054)	0.12 (0.0054)	0.16 (0.0076)
Moisture Content at 30-60 cm (g g^{-1})	0.11 (0.0060)	0.16 (0.0060)	0.17 (0.0080)
Moisture Content at 60-90 cm (g g^{-1})	0.11 (0.0042)	0.16 (0.0034)	0.17 (0.0044)
Soil Nitrate (kg ha^{-1} N)	13.8 (0.85)	19.7 (0.85)	34.4 (1.1)

Soil Health Metrics

Soil health metrics such as total carbon and aggregate stability were measured in SWCRC1 in July 2018. Though not significant at an alpha level of 0.05 ($p=0.10$), cover crop treatments show a higher average total soil carbon content (0.76% total C ± 0.02) relative to the fallow treatment (0.72% total C ± 0.03). Mean weight diameter of aggregates in cover crop treatments (399 um ± 67) is also slightly greater than that of the fallow treatment (374 um ± 100). Though these metrics typically take some time to change, it seems that there are soil health increases associated with cover crop treatments after two full cover crop cycles.

CONCLUSIONS

In dryland systems such as on the Colorado Plateau, cover crops can often negatively impact cash crop productivity, presenting a trade-off in terms of productivity and soil health. Early results from the field experiments presented here clearly highlight this trade-off, particularly following fall-planted cover crops, which tend to produce the most biomass (and thus use the most water). As precipitation is extremely low in the region and water is considered to be a major limitation to production, this cash crop penalty is likely due to lower soil moisture observed in cover crop plots. However, lower available nitrogen assimilated to cover crop biomass could also be limiting wheat yields following a cover crop.

Nonetheless, as soil degradation becomes a greater concern on the Colorado Plateau and farm longevity is threatened, soil health benefits (including those for water capture and storage) could justify this decrease in cash crop productivity. After only two cover crop cycles, there are promising trends in soil health metrics such as aggregation and total soil carbon. Improvements in soil structure and fertility such as these could have important implications for water capture, nutrient retention, and erosion control in the long-term, and could potentially help reduce the yield penalty observed here. Field experiments will be continued at least through 2021, and we will continue to monitor these metrics to assess the potential for cover crops to improve soil health in the long-term.

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